

## Vehicle Information

### Overview

Included in the demonstration were 111 vans powered by liquid and gaseous fuels and electricity. The CleanFleet vans used liquid and gaseous alternative fuel technologies that were available for commercial service in 1992, met FedEx requirements for operations, and were backed by the three manufacturers—Ford, Chrysler, and Chevrolet. Pertinent aspects of the vehicle technologies used with each of the fuels evaluated are described below.

- The propane gas vans from Ford and Chevrolet were gasoline vans modified to operate on propane gas using IMPCO Technologies, Inc. systems. The Ford vans were equipped with IMPCO's adaptive digital processor (ADP) system. The Chevrolet vans were equipped with the newer generation advanced fuel electronic (AFE) system.
- The Chevrolet CNG vans were gasoline vans modified to operate on CNG using IMPCO's AFE system. The Ford CNG vans were built especially for the project to operate on CNG. The Dodge CNG vans were among the first production CNG vans.
- The M-85 vans were Ford flexible-fuel vans, operating strictly on M-85.
- The RFG and unleaded control vans were standard, gasoline-powered, production vans.
- The electric vans were G-Vans equipped with either lead-acid or nickel-cadmium batteries.

Table 1 contains selected vehicle and powertrain characteristics of the 111 CleanFleet vehicles. Control vehicles (i.e., vehicles that operated on regular unleaded gasoline) were acquired from each of the three major vehicle manufacturers who manufactured or modified vehicles to operate on the alternative fuels. It should be noted that, in addition to the engine changes required for operating the engines on the alternative fuels, some non-fuel related engine differences were demonstrated because of the relatively limited pool of engines from which to pick.

The problem of the limited pool from which to pick was severe for the electric vehicle category. Here, only one candidate van approached the various requirements for FedEx operations. This candidate was the G-Van, which featured technology that was neither highly developed nor current. Because there was a strong desire to include a broad spectrum of alternative fuels in the demonstration, it was decided to include the G-Vans, but to treat them as a special, restricted case in both (1) conducting the demonstration and (2) analyzing and reporting the results.

Ideally, all of the engine/vehicle combinations selected would have featured engines/vehicles comparable in size and performance. The 4.9-liter, in-line, 6-cylinder gasoline engine in a full-size Ford Econoline Van is in widespread use by FedEx. The gross vehicle weight rating (GVWR) of this van is 7,200 pounds. The closest General Motors engines available at the start of the demonstration (1992) were a 4.3-liter V6 and a 5.7-liter V8. At that time, a gaseous fuel compatible version of the 8.6:1 compression ratio, 5.7-liter, V8 was available, but a gaseous fuel compatible version of the 4.3-liter V6 was not. Operating a gasoline engine with a given displacement on a single throttle body gaseous fuel system without

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**Table 1. Selected Powertrain and Vehicle Specifications**

Location	Fuel	Manufacturer	Model	Number of Vans	Curb Weight (lbs)	Powertrain <sup>(a)</sup>	Engine Oil Specifications <sup>(b)</sup> and Special Engine Materials
Irvine	CNG	Chevrolet	G30	7	5,462	5.7L IMPCO Throttle Body Fuel V8 8.6:1 CR Hp N/A	Chevron DELO 15W40 Hardened Valves and Seats Chrome Compression Rings
		Dodge	B350	7	5,122 <sup>(c)</sup>	5.2L SMPI V8 9.08:1 CR 200 Hp	Chevron DELO 15W40 Hardened Valve Seat Inserts
		Ford	E250	7	5,782	4.9L SMPI In-line 6 Cyl. 11.0:1 CR Hp N/A	Chevron DELO 15W40 Hardened Valve Seat Inserts
Log Angeles	RFG	Chevrolet	G30	7	4,956	4.3L CPI HD V6 8.6:1 CR 155 Hp	Chevron DELO 15W40 Standard Materials
		Dodge	B350	7	4,812	5.2LSMPI V8 9.08:1 CR 230 Hp	Chevron DELO 15W40 Standard Materials
		Ford	E250	7	5,490	4.9L MPI In-line 6 Cyl. 8.8:1 CR 150 Hp	Chevron DELO 15W40 Standard Materials
Rialto	Propane Gas	Chevrolet	G30	7	5,128	5.7L IMPCO Throttle Body Fuel V8 8.6:1 CR Hp N/A	Chevron DELO 15W40 Hardened Valves and Seats Chrome Compression Rings
		Ford	E250	13	5,379	4.9L IMPCO Throttle Body Fuel In-line 6 Cyl. 8.8:1 CR Hp N/A	Chevron DELP 15W40 Hardened Valves Hardened Exhaust Seat Inserts

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**Table 1. Selected Powertrain and Vehicle Specifications (Continued)**

Location	Fuel	Manufacturer	Model	Number of Vans	Curb Weight (lbs)	Powertrain <sup>(a)</sup>	Engine Oil Specifications <sup>(b)</sup> and Special Engine Materials
Santa Ana	M-85	Ford	E250 <sup>(d)</sup>	20	5,526	4.9L SMPI In-line 6 Cyl. 8.8:1 CR Hp N/A	Lubrizol MFV 10W30 Hardend Valves and Seats
Culver City	Electric	Conceptor	G-Van	2	7,756	52 Hp DC Traction Motor	
Irvine, Los Angeles, Rialto	Unleaded	Chevrolet	G30	9	4,956	4.3L MPI HD V6 8.6:1 CR 155 Hp	Chevron DELO 15W40 Standard Materials
Irvine, Los Angeles		Dodge	B350	6	4,812	5.2LSMPI In-line 6 Cyl. 8.8:1 CR 150 Hp	Chevron DELO 15W40 Standard Materials
Irvine, Los Angeles, Rialto, Santa Ana		Ford	E250	12	5,490	4.9L MPI In-line 6 Cyl. 8.8:1 CR 150 Hp	Chevron DELO 15W40 Standard Materials

<sup>(a)</sup> All vehicles were equipped with automatic transmissions except for the electric vehicles, which were built with a transmission/drive train that provided a single gear ratio in both forward and reverse. Abbreviations: CPI = central port fuel injection, CR = compression ratio, DC = direct current, Hp = horsepower, SMPI = sequential multiport fuel injection, HD = heavy duty, N/A = not available.

<sup>(b)</sup> Oil capacity in all vehicles is six quarts including the amount in the filter. Old filters were replaced at each oil change. Filters are Motorcraft FL-1A (or the AC Delco equivalent).

<sup>(c)</sup> Weight shown is for Dodge CNG van with fourth tank added.

<sup>(d)</sup> Ford M-85 vans are flexible fuel vehicles (FFV) that were operated strictly on M-85.

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increasing the compression ratio or making other performance enhancements can result in a loss of power of about 20 percent. Therefore, it was decided to use the 155-horsepower, 8.6:1 compression ratio, 4.3-liter V6 for the Chevrolet control vehicles and the larger (but same 8.6:1 compression ratio) 5.7-liter V8 (which is rated at about 190 horsepower on gasoline) as the basic engine for the Chevrolet natural gas and propane gas vehicles.

Dodge's closest available CNG engine was a newly released 5.2-liter V8 option, featuring sequential multi-port fuel injection and a compression ratio of 9.08:1. Ford was able to offer a CNG gas version of their 4.9-liter, in-line, 6-cylinder engine featuring both a higher compression ratio (i.e., 11:1 versus 8.8:1) and multi-port fuel injection. Ford also made available a propane gas prep package engine for the propane vehicles, which was fitted with an IMPCO throttle body fuel injection system.

The electric G-Vans used 52 horsepower DC traction motors and a "transmission" with a single gear ratio in both forward and reverse.

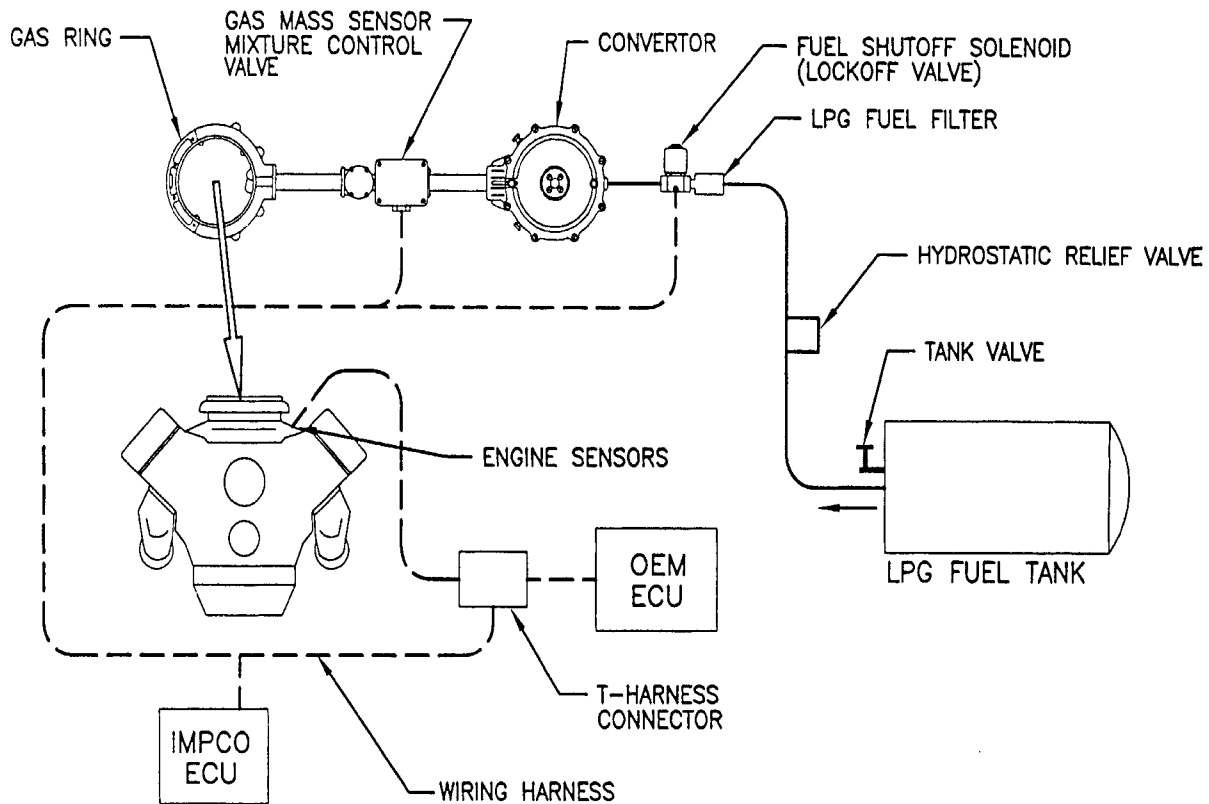
### Fuel System Technologies

**Propane Gas.** The Chevrolet propane gas vans were originally built to operate on gasoline, but featured special V8, 5.7-liter gaseous fuel compatible engines. These vans were subsequently modified to operate on propane using IMPCO's AFE system. This is a microprocessor-based, electronic control unit (ECU), engine management system that controls spark and exhaust gas recirculation (EGR) functions to provide optimum engine performance. AFE's operational functions interacted with the original equipment manufacturer (OEM) vehicle's on-board computer. The AFE strategy allowed the OEM on-board diagnostic routines to remain operational at all times. The compression ratio was not changed in the modifications; it remained at 8.6:1.

A schematic diagram of IMPCO's AFE system is shown in Figure 1. Liquefied petroleum gas (LPG) is drawn from the tank through the fuel filter and lockoff valve to the convertor, where it is changed from a liquid to a gas and the pressure is regulated. The gas moves through the gas mass sensor to the gas ring, and then through the throttle body into the engine.

The Ford propane gas vans featured 4.9-liter, in-line, 6-cylinder LP prep package engines. The vehicles were modified to operate on propane gas using IMPCO's ADP fuel system. The ADP is a stand-alone, alternative fuel system, with an electronic, closed loop feedback controller. The electronic controller features a 16-cell block learn memory that provides stoichiometric fuel mixtures when used in conjunction with IMPCO's air/fuel mixer. The ADP controller is not capable of interacting with the OEM's on-board computer. The compression ratio was not changed in the modification process; it remained at 8.8:1.

A schematic diagram of the ADP system is shown in Figure 2. Liquid propane fuel is drawn from the tank through a fuel filter and lockoff valve to the convertor, where it is changed to a gaseous state and the pressure is regulated. The propane is then drawn through IMPCO's air/fuel mixer and the throttle body into the engine.

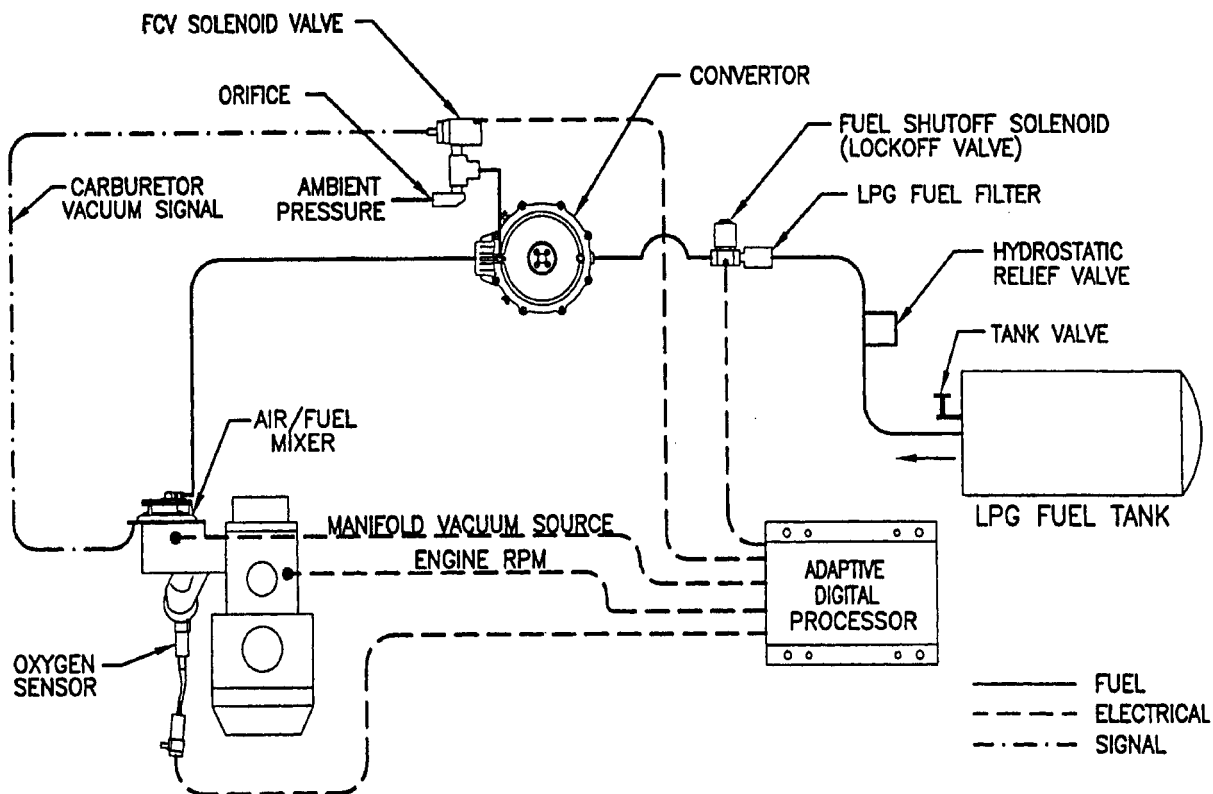


**Figure 1. IMPCO's AFE System.**

The ADP controller uses manifold absolute pressure (MAP) and engine speed to control gas pressure within the alternative fuel system. The ADP system also uses oxygen sensor input to update fuel system data stored in the adaptive memory. By using stored stoichiometric mixture data, the ADP can instantly adjust the fuel system to meet the required combustion characteristics. The fuel adjustment function is accomplished by sending a duty cycle signal back from the ADP to the fuel control valve that varies the fuel pressure to the IMPCO feedback mixer. This process will continuously readjust the air/fuel ratio over the entire service life of the vehicle. Block learn memory is also used to compensate for engine wear and degradation.

**Compressed Natural Gas.** The Chevrolet compressed natural gas vans were built originally to operate on gasoline, but featured V8, 5.7-liter gaseous fuel compatible engines. These vans were subsequently modified to operate on CNG using IMPCO's AFE system. This is a microprocessor-based engine management system that controls spark and EGR functions to provide optimal engine performance. AFE's operational functions interact with the OEM vehicle's on-board computer. The AFE strategy allows the OEM on-board diagnostic routines to remain operational at all times. The compression ratio was not changed during the modification process; it remained at 8.6:1.

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**Figure 2. IMPCO's ADP System.**

High pressure (up to 3,000 psi) CNG is drawn from the tank through the primary regulator and lockoff valve to the secondary regulator. The gas moves through the gas mass sensor to the gas ring, and then through the throttle body into the engine.

The Dodge vans used in the CleanFleet demonstration were originally manufactured to operate on natural gas. The Dodge CNG vehicles had an unexpectedly short range (80 to 90 miles) in FedEx service. In February and March 1993, one extra fuel tank (i.e., a fourth tank) was installed on each of the seven Dodge vans, giving them a total fuel capacity equivalent to 16 gallons of gasoline. Larger tanks were not installed because vehicle components would have had to be moved to accommodate them. The fourth tanks were installed by NGV Technologies under contract to Southern California Gas Company.

The Ford CNG vehicles were provided ready to operate on natural gas and featured 4.9-liter, in-line, 6-cylinder engines with sequential, multi-port, electronic fuel injection and a compression ratio of 11:1. After receipt, they were modified to allow them to be fueled with the CNG dispenser nozzle used by CleanFleet. The fill fitting orientation on the tank prevented the dispenser nozzle from connecting to the Ford tank; therefore, the fill fittings were changed on all the Ford vehicles.

**M-85.** In March 1992, 23 Ford vans were delivered to the demonstration site, 20 of which were to be modified by Ford to operate on M-85 and three to be used as control vehicles. The 20 M-85 vans were flexible fuel vehicles (FFV) designed to use methanol-gasoline mixtures ranging from zero to 85 percent methanol. These vans used sequential, multi-port, electronic fuel injection. They were equipped with six fuel injectors plus a seventh “cold-start” injector, which is not needed in the southern California climate.

**Electric.** Southern California Edison (SCE) provided two early-prototype electric G-Vans (powered by lead-acid batteries) for the demonstration in April 1992, anticipating that the G-Vans would be replaced when new designs became available. These vans were modified for electric propulsion by Conceptor Corporation, a subsidiary of Vehma International, Inc., and began service in Culver City in April 1992. The lead-acid battery pack weighed about 1,140 kilograms, and it was composed of 36 six-volt monoblocks. A Chloride, Inc. charger that provided 35 amperes of direct current was used. Midway through the demonstration, one of the two G-Vans was equipped with nickel-cadmium batteries. The nickel-cadmium battery pack weighed about 850 kilograms, and it was composed of 34 monoblocks. A LaMarche charger with an output of 46 amperes was used.

### Maintenance Policies and Practices

All of the engines used in the CleanFleet project were built with conventional wet oil sumps that hold six quarts of oil, including the oil filter. All of the engine sumps, except those running on M-85 fuel, were filled with a mineral-based, 15W40 oil sold under the Chevron DELO name. A Lubrizol MFV 10W30 oil was used in the Ford vehicles operating on M-85 fuel. While the exact additive packages for each oil were not provided by the manufacturers, both appeared to have conventional extreme pressure and antiwear additives based on common zinc and phosphorus compounds. The lubricants also appeared to have additives containing calcium or magnesium that are often associated with detergent and antioxidation additives. The Chevron oil is the standard oil for FedEx fleet vehicles, and the Lubrizol oil was formulated for use in flexible-fuel vehicles. No additive package development was performed specifically for this project.

Fleet vehicles used by FedEx on its routes are generally considered to be in “severe service” as defined by the OEMs. This means the vehicles may be subject to prolonged periods of idling, low-speed operation, or frequent starts and stops. While the manufacturers do not typically prescribe maintenance procedures for fleet vehicles, a maintenance schedule based on the “severe service” guidelines for gasoline-powered passenger vehicles is a good guideline to follow. These guidelines usually recommend oil changes every three months, chassis lube every other oil change, a coolant change once a year, a transmission filter and fluid change at least every two years, and air filter replacement as needed up to every two years. Actual fleet maintenance schedules were proposed by FedEx and agreed to by the OEMs for warranty purposes.

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FedEx maintains a policy for preventive maintenance on its delivery trucks to ensure safe operation of its fleet and to prolong the life of the vehicles. Preventive maintenance is scheduled every 12 weeks (84 days). Engine oil is changed at this time or more frequently if a panel van accumulates more than 6,000 miles during this period. FedEx fleet managers at the district level can implement a schedule more frequent than 84 days if warranted. (Three fleet managers had responsibility for vehicles at the five demonstration sites.) Most panel vans in CleanFleet operations did not accumulate more than 6,000 miles in an 84-day period. Only four CleanFleet vehicles had a more frequent schedule for oil changes. These were vans that operated on long routes in the eastern portion of the South Coast Air Basin. These vans had an eight-week interval between oil changes. Three propane gas vans and one unleaded control van had an eight-week schedule for oil change. The schedule of oil changes for vans operated out of the propane site changed because the vans were rotated among delivery routes for the CleanFleet project. Route characteristics at the other sites were such that modifications of the oil change schedule were not required.